Natural Gas Infrastructure
R&D Roadmap Update II

Pointe South Mountain Resort, Phoenix Arizona
February 8, 2004

INTRODUCTION

The U.S. Department of Energy's National Energy Technology Laboratory hosted the **Natural Gas Infrastructure R&D Roadmap Update II,** in Phoenix Arizona on Sunday, February 8, 2004. Forty experts from industry and government attended the roadmap update to provide technology-focused insights regarding current issues facing natural gas infrastructure. The meeting examined both near-term and long-term technology needs and provided valuable feedback on the existing infrastructure roadmap priorities and the portfolio of projects supported by NETL.

BASELINE

Participants were divided into two groups, A and B. A single focus questions was presented to both groups for initial brainstorming:

1. What are the key trends and drivers that affect natural gas infrastructure with a focus on the past 2 years?

There was no prioritization voting for this initial board. Instead, it served as a warm-up and a background for the broad crosscutting exercise. Each group was then shown the results of the previous two roadmapping workshops on pre-printed cards. Participants were asked to develop additional needs and assess gaps using results from the initial brainstorming session. Two prioritization votings occurred for each group. First, each group voted on the new needs that were generated, and then each group voted on the existing needs that had already been identified. The intent for the latter voting was to reestablish what is currently considered top priorities.

PRIORITY LISTS

<u>New Ideas</u>

Group A
Corrosion – stress cracking – we don't know what we don't know
3rd Party – Integrated GPS with GIS for real time mapping
Leak Detection – Quantify methane emissions
General – Accurate pipe location

3rd Party – Cost effective pipe feature for locating and marking
Smart Pipe – Cost effective high pressure pipe
Compressors – Research to improve reliability and efficiency
Fuel Measurement – Monitor & measure gas quality economically
Other – Financial recovery efficiency & reliability projects

Group B
Construction - Need cost effective ways to get pipe in ground and timely
Construction- Cost effective R&R of aging plastic pipe w/ trenchless
Gas Quality - Disparity of gas quality domestic and foreign
Leak Detection - Visualization
Compressors - Increase efficiency and economics of compressors
Compressors - Improve RAM of compressors
Other - LNG infrastructure & impact on existing pipelines
Other - More throughput with existing pipelines T&D

Previous Ideas

Group A
Sensors – Inspection tools for non-piggable mains
3rd Party – Right of way monitoring
Leak Detection – Cost effective leak detection and pinpointing
Leak Detection – Develop laser technology for above ground lines
Compressors – Improve compressors and next generation
Compressors – Advanced multi-function compressor technology
Other – Conduct vulnerability assessment for natural gas systems

Group B
Sensors - Inspection tools for non-piggable mains
Robotic - Advanced robotic technology for non-piggable transmission
Underground - 3-D subsurface facility locating techniques
Repair - Lower the cost on in-the-pipe repair technologies
Smart Pipe - Materials research for high-pressures lines
Compressors - Improve compressors and next generation
Security - Conduct vulnerability assessment for natural gas

CROSSCUTTING RESULTS

New Needs

Gas quality
Compressors RAM (reliability, availability, maintainability)
New construction cost effectiveness

Previous Needs

Sensors - Inspection tools for non-piggable mains
Compressors - Improve compressors and next generation
Security - Conduct vulnerability assessment for natural gas

GROUP A RESULTS

New Needs

New categories headings included general under inspection, fuel measurement under operational, technology implementation and acceleration. Participants prioritized new research needs using 3 regular votes. There was one new top vote getter with 5 votes, two new needs got 3 votes each, and an additional six new needs got 2 votes each.

Group A

NAME	ORGANIZATION
Dick Benson	LANL
Rick Blake	Lawrence Livermore Lab.
Bruce Campbell	GTI
Sam Clowney	El Paso
Dan Driscoll	USDOE-NETL
Christopher Freitas	US DOE- FE
Mike Hightower	SNL
Winston Johnson	El Paso
Karl Lang	SAIC
Marti Marek*	Southwest Gas
Jim Merritt	DOT
Graham Midgley	Heath Consultants
John Mowery	Ariel Corporation
Bruce Nestleroth	Battelle
Gerald Paulus	City of Mesa
Patricia Squires	Enbridge Gas Distribution
Vic Viteri	Clean Energy Systems

* Report out person

FACILITATOR: JACK EISENHAUER, ENERGETICS

- 5) Corrosion – stress cracking – we don't know what we don't know
- 3) 3rd Party – Integrated GPS with GIS for real time mapping
- 3) Leak Detection – Quantify methane emissions
- 2) General – Accurate pipe location
- 2) 3rd Party – Cost effective pipe feature for locating and marking
- 2) Smart Pipe – Cost effective high pressure pipe
- 2) Compressors – Research to improve reliability and efficiency
- 2) Fuel Measurement – Monitor & measure gas quality economically
- 2) Other – Financial recovery efficiency & reliability projects

Previous Needs

The previous column headings were as follows: automation technologies, sensors, robotic inspection systems, 3rd party damage, leak detection, underground imaging, repair technologies and tools, smart pipe technology, pipe liners, compressors, modeling, corrosion, and other. Participants prioritized old existing research needs using 4 regular votes. There was one top vote getter with 5 votes, two needs got 4 votes each, and an additional four needs each received 3 priority votes:

- 5) Sensors – Inspection tools for non-piggable mains
- 4) 3rd Party – Right of way monitoring
- 4) Leak Detection – Cost effective leak detection and pinpointing

- 3) Leak Detection – Develop laser technology for above ground lines
- 3) Compressors – Improve compressors and next generation
- 3) Compressors – Advanced multi-function compressor technology
- 3) Other – Conduct vulnerability assessment for natural gas systems

GROUP A
TABLE 1 – KEY R&D NEEDS THAT AFFECT NATURAL GAS INFRASTRUCTURE

INSPECTION TECHNOLOGIES				REMOTE SENSING		
AUTOMATION TECHNOLOGIES	**SENSORS**	**ROBOTIC INSPECTION SYSTEM**	**GENERAL**	**3RD PARTY DAMAGE PREVENTION**	**LEAK DETECTION**	**UNDERGROUND IMAGING**
✓ Improved system for data acquisition ✓ *Develop lost cost standard communication equipment (plug & play)* ● ●	✓ Develop multifunctional sensors, residual life, damage, mapping ✓ In-line inspection tool ● ✓ *Inspection tools for non-piggable mains* ● ● ● ● ● ✓ *Develop magnetic flux leakage tools for better pit geometry* ● ☐ **Small internal inspection tools (2" maws)** ▲	✓ *Advanced robotic technology for non-piggable transmission mains*	☐ **General inspection method to objectively set re-inspection intervals** ▲ ☐ **Inspection for pipeline wellness for new pipelines. Help NIMBY problem** ▲ ☐ **Accurate pipe location and description of effects (SCC...)** ▲▲	✓ System of sensors and communication devices to detect when someone is near ● ● ☐ **Develop warning systems on excavation equipment** ● ✓ *Right-of-way monitoring* ● ● ● ● ✓ *Develop suite of cost-effective surveillance techniques* ✓ *Develop smart pipe technology w/wireless remote sensing devices* ● ☐ **Integrated GPS with GIS, for real time mapping that is immediate and accurate** ▲▲▲ ☐ **Cost effective pipe feature locating & marking RFID** ▲▲ ☐ **Emergency response abatement** ▲	✓ Laser optical methane and ethane detectors w/speed and accuracy ● ● ✓ Cost-effective leak detect-ion and pin-pointing ● ● ● ● ✓ *Develop laser technology to detect leaks in above ground lines* ● ● ● ✓ **Quantify methane emissions** ▲▲▲	✓ Underground inspection technology to aid construction and repair ✓ 3-D subsurface facility locating techniques ● ● ✓ Develop better imaging for locating underground pipes ✓ More sophisticated underground directional drilling technology ✓ Sensors to guide boring tools to detect other facilities ✓ Locatable plastic (non-metallic) pipe (imbedded material tag) ✓ *Boring equipment with real-time damage detection* ☐ **Harmonic drill, directional boring, tools that use harmonic resonance to drill through soil but not through pipe**

Bullets
✓ = DOE project(s) exists that address this need
☐ = No DOE project exists for

Voting
Green Dots = priority vote for existing needs
Red Triangles = priority vote for new needs

Type
Regular = Natural Gas Infrastructure Roadmap, June 2000
Italic = *Roadmap Update I, January 2002*
Bold = **Roadmap Update II, February 2004**

GROUP A

TABLE 1 – KEY R&D NEEDS THAT AFFECT NATURAL GAS INFRASTRUCTURE (CONTINUED)

MATERIALS DEVELOPMENT			OPERATIONAL TECHNOLOGIES			
REPAIR TECHNOLOGIES AND TOOLS	**SMART PIPE TECHNOLOGY**	**PIPE LINERS**	**COMPRESSORS**	**MODELING**	**CORROSION**	**FUEL MEASUREMENT**
✓ *Robotics repair of internal corrosion* ✓ *Lower the cost of in-the-pipe repair technologies using new design*	✓ Smart pipes that are self-healing and self-monitoring ☐ High pressure plastic pipe materials ● ☐ Develop high pressure composite pipe ☐ Materials optimization: new composites, corrosion resistant, high pressure, low cost ● ● ✓ *Take sensing to level of "skin" for intelligent pipelines* ✓ *Materials research for high pressure lines* ● ☐ **Cost effective higher pressure distribution pipe** ▲▲	✓ Lining technology to upgrade low pressure lines to higher pressure ● ☐ Development of smart, multifunctional pipeline coating	✓ Improve compressors and next generation compressors ● ● ● ✓ Lower cost emission control compressor engines ● ● ✓ Modeling algorithms for compressor station components ✓ *Advanced multi-function compressor technology* ● ● ● ☐ **Improved sensors for comp. machinery** ▲ ☐ **Research to improve compression reliability & efficiency** ▲▲ ☐ **Lower emission comp. equipment without after treatment** ▲ ☐ **More flexibility comp. equipment** ● ☐ **Advanced engine designs to burn new species fuel (partially oxidized to reduce environmental protection)**	✓ Develop predictive pipe failure models ● ✓ *Develop information exchange protocols* ✓ *Forecasting system of generation and LDC dispatching* ☐ **Cross company pipeline modeling to determine interconnect opportunities to increase capacity** ▲ ☐ **Data integration technology** ▲ ☐ **Develop non-parametric statistical tools/techniques to monitor real time compressor performance and degradation**	☐ **Stress corrosion, cracking, we don't know what we don't know** ▲▲▲▲▲ ☐ **Corrosion – internal/external and ways to avoid** ☐ **Above ground corrosion** **- Risers** **- MSA**	☐ **Monitoring and measuring gas quality economically** ▲▲ ☐ **Low cost energy measurement technology to accurately measure BTU – this could increase pipeline capacity 10-15%** ▲ ☐ **Gas quality analysis** ▲

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GROUP A

TABLE 1 - KEY R&D NEEDS THAT AFFECT NATURAL GAS INFRASTRUCTURE (CONTINUED)

OTHER	OTHER	TECHNOLOGY IMPLEMENTATION/ ACCELERATION
☐ Study how to improve permitting process ☐ More realistic economic model for analyzing construction benefit and risk ✓ Develop novel on-site storage technology ✓ Develop improved storage facilities ● ☐ **Financial recovery – efficiency and reliability projects ▲▲** ☐ **Cumulative effects on row** ☐ **Distributed storage – residential, commercial point of use storage ▲** ☐ **Pipeline construction technology that responds to environmental concerns (footprint) ▲**	✓ *Secure SCADA* ✓ *Conduct vulnerability assessment for natural gas systems ● ● ●* ✓ *National emergency warning system ●* ✓ *Nationwide energy control system to be activated in an emergency*	☐ **Process for code changes for new technologies quickly and rationally** ☐ **How do we move research projects to commercialization more rapidly** ☐ **Academic programs to train people for NG industry or funding research ▲** ☐ **Miniature – Nano-technology for internal pipe inspection – what's available**

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GROUP A

WHAT ARE THE KEY TRENDS AND DRIVERS THAT AFFECT NATURAL GAS INFRASTRUCTURE?

MARKET AND PRICES	OPERATIONAL AND BUSINESS NEEDS	TECHNOLOGY	REGULATIONS, CODES, ENVIRONMENTAL ISSUES	INDUSTRY STRUCTURE
▪ Natural gas price transparency suspect ▪ Price/demand variability/instability ▪ New federal regulations on coal plants and demand for natural gas and gas plants ▪ Bottlenecks between supply and demand centers ▪ Market profile changes ▪ Sources of natural gas supply shifting from SW/SE U.S. to NW U.S. & Canada	▪ Integrity Management ▪ Data integration/communication ▪ HP distribution pipe ▪ Sensor technology for comp. equipment ▪ Pipeline integrity – new tools ▪ New pipeline construction difficult – update ▪ SCC issues ▪ Trend to higher pressure pipelines ▪ Increasing understanding of need for risk management - Plastic - Steel ▪ Inspection for all defect types. B31.85 ▪ System Monitoring and control issue ▪ Development of natural gas storage both non-traditional underground and safety of above ground ▪ Include need for compression flexibility ▪ Machinery life extension	▪ Advanced recip compressor technology (GMRC) efficiency/reliability ▪ Cheaper distributed comm. and sensors RFID	▪ Air quality issues associates with natural gas combustion ▪ More government regulations to need ▪ Sustainability base ▪ New infrastructure for stranded gas reserves, environmental/ecological issues ▪ Demand for electricity confines to ? & natural gas fills role or peak power ? ▪ Antiquated regulations that don't align with new materials technologies ▪ No incentives for increased fuel efficiency	▪ Technology funding constraints (utility) ▪ Determination of knowledge base ▪ Incentive reg./PBR and productivity improvements

GROUP A

WHAT ARE THE KEY TRENDS AND DRIVERS THAT AFFECT NATURAL GAS INFRASTRUCTURE? (CONTINUED)

GAS QUALITY	SECURITY AND RISK MANAGEMENT PROTECTION	PUBLIC POLICIES
▪ LNG gas quality ▪ Gas quality (BTU values) ▪ Security and risk management protection	▪ LNG imports and safety, security, reliability	▪ Public education vs. NIMBY ▪ Construction PL ▪ LNG ▪ President's reference to the hydrogen economy ▪ X-border issues (Regulatory standards) ▪ More emphasis needed on commercialization

GROUP B RESULTS

New Needs

Group B

NAME	ORGANIZATION
Rodney Anderson	USDOE-NETL
Rick Baker	USDOE-NETL
Robert Bass	Southwest Research Inst.
Paul Brooks	Pacific Gas & Electric
Jeff Colwell	Battelle
Gene Crawford	Memphis Light Gas & Water
John DeVenz	Enbridge Gas Distribution
Glyn Hazelden*	GTI
Frank McRae	City of Mesa
Jeff Moore	Dresser-Rand
George Ragula	Public Service Elec. & Gas
Eric Thomas	El Paso
Robert Torbin	Foster-Miller
George Vradis	Northeast Gas Association
Jay Willer	GTI
Ted Williams	AGA
Jeff Wright	FERC

***** Report out person

FACILITATOR: KEVIN MOORE, ENERGETICS

There were 15 active participants in Group B. Funding or the future lack thereof was of importance to the group for this and the crosscutting session. A few were outspoken on this lack of funding issue, and they want some commitment for DOE for a long-term solution to pending R&D funding halts. Another pervasive need is the general notion of developing quicker and cheaper pipeline installation techniques. DOE discouraged priority voting on these needs because they effectively cannot do anything about it.

New categories headings included security surety, gas quality, construction, major objectives, and R&D funding. The latter two were encompassing ideas that crosscut all endeavors and were not allowed to vote on because rally no specific need but instead a general concept. Participants prioritized new research needs using 3 regular votes. There was one top vote getter with 9 votes, two needs got 5 votes each, and another 5 needs got 4 votes each.

- 9) Construction - Need cost effective ways to get pipe in ground and timely
- 5) Construction- Cost effective R&R of aging plastic pipe w/ trenchless
- 5) Gas Quality - Disparity of gas quality domestic and foreign
- 4) Leak Detection - Visualization
- 4) Compressors - Increase efficiency and economics of compressors
- 4) Compressors - Improve RAM of compressors
- 4) Other - LNG infrastructure & impact on existing pipelines
- 4) Other - More throughput with existing pipelines T&D

Previous Needs

The previous column headings were as follows: automation technologies, sensors, robotic inspection systems, 3rd party damage, leak detection, underground imaging, repair technologies and tools, smart pipe technology,
pipe liners, compressors, modeling, corrosion, and other. The old security category was amended to add surety and therefore considered a new category. Participants prioritized old existing research needs using 4 regular votes. There was one top vote getter with 7 votes and an additional 6 needs that each received 4 priority votes:

- 7) Sensors - Inspection tools for non-piggable mains
- 4) Robotic - Advanced robotic technology for non-piggable transmission mains
- 4) Underground - 3-D subsurface facility locating techniques
- 4) Repair - Lower the cost on in-the-pipe repair technologies
- 4) Smart Pipe - Materials research for high-pressures lines
- 4) Compressors - Improve compressors and next generation
- 4) Security - Conduct vulnerability assessment for natural gas

GROUP B

TABLE 2 - KEY R&D NEEDS THAT AFFECT NATURAL GAS INFRASTRUCTURE

INSPECTION TECHNOLOGIES			REMOTE SENSING		
AUTOMATION TECHNOLOGIES	**SENSORS**	**ROBOTIC INSPECTION SYSTEMS**	**3RD PARTY DAMAGE PREVENTION**	**LEAK DETECTION**	**UNDERGROUND IMAGING**
✓ Improved system for data acquisition ✓ *Develop low cost standard communication equipment (plug & play)*	✓ Develop multifunctional sensor, residual life, damage, mapping ● ● ✓ In-line inspection tool ✓ *Inspection tools for non-piggable mains* ● ● ● ● ● ● ● ✓ *Develop magnetic flux leakage tools for better pit geometry*	✓ *Advanced robotic technology for non-piggable transmission mains* ● ● ● ●	✓ System of sensors and communication devices to detect when someone is near ● ● □ Develop warning systems on excavation equipment ● ● ✓ *Right-of-way monitoring* ✓ *Develop suite of cost-effective surveillance techniques* ✓ *Develop smart pipe technology with wireless remote sensing devices* ●	✓ Laser optical methane and ethane detectors w/speed and accuracy ● ● ✓ Cost-effective leak detection and pinpointing ● ✓ *Develop laser technology to detect leaks in above ground lines* □ **Visualization** ▲ ▲ ▲ ▲	✓ Underground inspection technology to aid construction and repair ✓ 3-D subsurface facility locating techniques ● ● ● ● ✓ Develop better imaging for locating underground pipes ● ● ✓ More sophisticated underground directional drilling technology ● ✓ Sensors to guide boring tools to detect other facilities ● ● ✓ Locatable plastic (non-metallic) pipe (imbedded material tag) ✓ *Boring equipment with real-time damage detection*

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GROUP B
TABLE 2 - KEY R&D NEEDS THAT AFFECT NATURAL GAS INFRASTRUCTURE (CONTINUED)

MATERIALS DEVELOPMENTS			OPERATIONAL TECHNOLOGIES		
REPAIR TECHNOLOGIES AND TOOLS	**SMART PIPE TECHNOLOGY**	**PIPE LINERS**	**COMPRESSORS**	**MODELING**	**CORROSION**
✓ *Robotics repair of internal corrosion* ✓ *Lower the cost of in-the-pipe repair technologies using new design* ● ● ● ●	✓ Smart pipes that are self-healing and self-monitoring ☐ High pressure plastic pipe materials ● ☐ Develop high pressure composite pipe ● ☐ Materials optimization: new composites, corrosion resistant, high pressure, low cost ✓ *Take sensing to level of "skin" for intelligent pipelines* ✓ *Materials research for high pressure lines* ● ● ● ●	✓ Lining technology to upgrade low pressure lines to higher pressure ☐ Development of smart, multifunctional pipeline coating	✓ Improve compressors and next generation compressors ● ● ● ● ✓ Lower cost emission control compressor engines ✓ Modeling algorithms for compressor station components ✓ *Advanced multi-function compressor technologies* ● ● ☐ **Increase efficiency and therefore economies** ▲▲▲▲ ☐ **Improve RAM reliability, availability, maintainability** ▲▲▲▲ ☐ **Variable rated compression** **- spare capacity** ▲	✓ Develop predictive pipe failure models ● ● ● ✓ *Develop information exchange protocols* ✓ *Forecasting system of generation and LDC dis-patching* ● ● ☐ **Data integration & analysis, e.g., MFL**	☐ **Advanced CP cathodic protection technologies** ▲

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GROUP B

TABLE 2 - KEY R&D NEEDS THAT AFFECT NATURAL GAS INFRASTRUCTURE (CONTINUED)

OTHER	NEW AREAS				
OTHER	**SECURITY SURETY**	**GAS QUALITY**	**CONSTRUCTION**	**Major Objectives***	**R&D Funding***
☐ Study how to improve permitting process ☐ More realistic economic model for analyzing construction benefit and risk ● ✓ Develop novel on-site storage technology ✓ Develop improved storage facilities ● ☐ **Hydrogen infrastructure for dispersion, delivery and combustion and standards** ▲ ☐ **LNG infrastructure and impact on existing pipelines** ▲▲▲▲ ☐ **More throughput with existing pipelines T&D** ▲▲▲▲	✓ *Secure SCADA systems* ● ● ✓ *Conduct vulnerability assessment for natural gas system* ● ● ● ● ✓ *National emergency warning system* ✓ *Nationwide energy control system to be activated in an emergency* ☐ **Response recovery phase** ▲	☐ **Disparity of gas quality domestic and foreign conflict with pipeline standards - how reconcile** ▲▲▲▲▲ ☐ **End-use performance** ☐ **Piping and machinery integrity performance** ☐ **Energy content measure**	☐ **Need cost effective ways to get pipe in ground and timely** ▲▲▲▲▲▲▲▲▲ ☐ **Guided boring technology** ▲ ☐ **Cost effective replacement and rehabilitation of aging plastic pipe systems with trench-less method** ▲▲▲▲▲	▪ Improved deliverability, security, operational efficiency - reduced costs - regulatory compliance	▪ Amount and dependability limits long-range planning ▪ Future funding sources

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GROUP B
WHAT ARE THE KEY TRENDS THAT ARE AFFECT NATURAL GAS INFRASTRUCTURE?

R&D FUNDING	COST EFFICIENCY	REGULATORY COMPLIANCE & INTEGRITY	NCREASED PIPELINE CAPACITY AND EFFICIENCY	PIPELINE SECURITY SURETY	COMPRESSION TECHNOLOGY RELIABILITY, MAINTABILITY
▪ Insufficient Industry R&D funds to make-up for GTI FERC Funding ending in 2004 ▪ Funding R&D GAP ▪ Changing players in infrastructure R&D funding and organizational interests	▪ Looking for labor saving technologies where money is spent especially surveying ▪ Cost effective technologies ▪ Cost effective replacement and rehabilitation of aging plastic pipe distribution systems utilizing trench-less methods ▪ Growing application of data interwire integrity techniques and need for analysis and validation like MFL data ▪ Alternative high pressure pipe materials - lower cost installation & O&M - i.e., composite plastic ▪ Guided boring technologies like keyhole	▪ Pipeline Safety Act 2003 – Inspections in high consequence area ▪ Detection, characterization and response to threats to pipeline integrity caused by Office of Pipeline Safety integrity rule ▪ Regulations on integrity management presenting significant costs of compliance ▪ Office of Pipeline Safety rule on pipeline integrity ▪ Advances sensors	▪ Perception/projection for 32 TCF demand. Not enough capacity in current pipeline ▪ Need cheaper and quicker pipe in ground ▪ Increased gas demand and power generation - Increase efficiency and throughput of existing pipelines ▪ Need for spare pipeline capacity – variable rated compression ▪ More throughput with existing pipelines ▪ 30 TCF moved out in time 2015 – 2020 ▪ How do we capture more gas supply with new technology from old and new sources	▪ Rapid response/ recovery for terrorist or natural disasters = delivery surety ▪ Establishment of Department of Homeland Security gas infrastructure security ▪ Utility infrastructure security is becoming an issue since 9-11 (hacking into SCADA) ▪ Emergency response - system shut-down - damaged - not damaged	▪ Replacement of aging compressors (many 30+ years old), no replacement parts ▪ More efficient and less emitting compression drivers

GROUP B

WHAT ARE THE KEY TRENDS THAT ARE AFFECT NATURAL GAS INFRASTRUCTURE? (CONTINUED)

GAS QUALITY	HYDROGEN	CATHODIC PROTECTION	LEAK SURVEY SYSTEMS	FACILITIES LOCATORS	LNG
▪ Disparity of gas quality and conflict with pipeline standards How to reconcile e.g., LNG condensable liquids interchange- ability of gas	▪ Conversion to hydrogen based energy system - natural gas conversion and infrastructure	▪ Advanced CP data management concepts to extend life of steel infrastructure.	▪ Advanced gas leak survey systems - laser, visualization, aerial	▪ Underground imaging of buried structures high reliability - Underground "x-ray" ▪ Underground facility location of non-gas and electric facilities	▪ Increased use of LNG in future ▪ Proper infrastructure to handle LNG imports

Natural Gas Infrastructure R&D Roadmap Update II

February 8, 2004
Phoenix, Arizona

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